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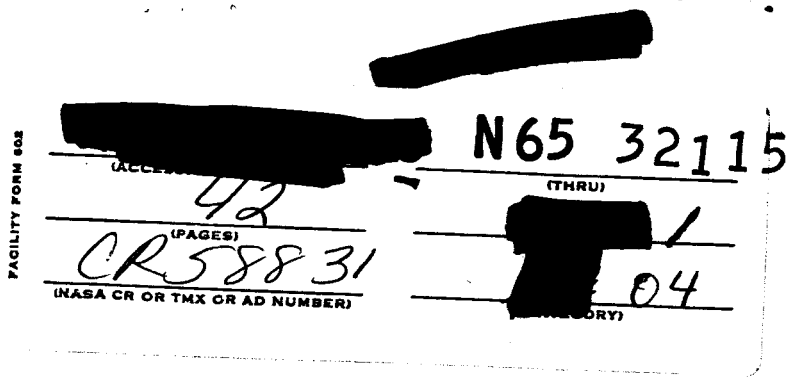

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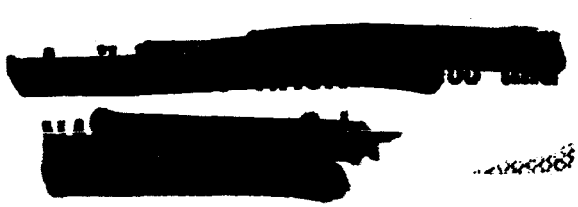

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Preface

This first progress report represents an overview of work in the M.I.T. Psychology Laboratories during the six-month period between June 1 and December 1, 1963. In the history of the M.I.T. Psychology Section, this period was a special one: It began near the end of the installation of our new laboratories in Building E10 - a move that had started in October, 1962. The period under review has also seen the rapid growth of the graduate training program to its present size of 15 graduate students, after the M.I.T. Corporation in its meeting of March, 1962, had sanctioned the offering of a doctorate in psychology at the Institute. The period under review is also noteworthy because it coincides with the receipt of generous aid for our research program from the U.S. Air Force Office of Scientific Research and from the National Aeronautics and Space Adminstration. Aid from the Air Force OSR in the form of a one-year grant enabled us to build up our shop facilities and some of the electrophysiologic apparatus essential for our work. The NASA grant, now in the first of three years of pledged support, has enabled us to acquire additional equipment and auxiliary personnel, and remains an important source of aid for most of the work described in the following pages.

I. Brain and Behavior (Physiological Psychology)

Work in this area proceeds by analyzing the functional significance of anatomic patterns as seen in the behavioral consequences of penetrating brain wounds in previously normal adults, in the lasting effects of early brain injury sustained by children, and in the various ways in which one can dissect brain function in experimental animals by means of cerebral ablation, electrical stimulation, recording, and chemical manipulation.

A. Studies of Effects of Brain Injury in Man

1. Adults. At the beginning of the period under review, we completed a preliminary survey of available cases of veterans with penetrating gunshot wounds of the brain - injuries incurred in World War II or the Korean Campaign - residing within the jurisdiction of the Boston Veterans Administration Regional Office. This detailed survey yielded 138 such cases, with proven loss of brain tissue due to penetrating missile. Twenty-one of these cases have been activated and are now under study, together with selected cases from an earlier group of such patients gathered in New York City by H.-L. Teuber and his co-workers. These groups will be supplemented, in the near future, by additional cases of brain lesions in adults, particularly those involving the basal ganglia. Specific studies, in progress or completed, include the following:

(a) Further Analysis of General (Nonspecific) Signs of Brain Injury in Man (R. G. Rudel and H.-L. Teuber). In line with earlier observations in this program, there seem to be symptoms of brain injury, in previously healthy adults, which appear irrespective of site of lesion, yet are probably correlated with size or severity of cerebral damage. These general symptoms coexist with exquisitely focal signs of injury to particular regions of the human forebrain. A new "nonspecific" (nonlocalizable) symptom of this sort has been disclosed by asking brain-injured men to bissect a Müller-Lyer pattern for 40 consecutive trials. In the normal adult, such repeated adjustments lead to progressive decline in the size of the illusion. In our patients, this diminution is less marked or absent; the degree of the change is correlated with degree of deficit revealed on hidden-figure tasks. Performance on such tests had previously been noted by us to be impaired in a nonspecific way after brain injury in any lobe and in either hemisphere (Rudel and Teuber, 1962).

(b) Further Study of Residual Vision in Scotoma. An unfinished task in the neuropsychology of vision is the exact assessment of visual capacities following destructive lesions of the central visual pathways, particularly the so-called projection areas in the human occipital lobe. Previous work from this laboratory had suggested that seemingly blind regions may have residual functions (Teuber et al., 1960), and that simple geometric patterns falling partly into areas of dense scotoma might be subjectively complete. Further studies of these phenomena are now in progress, particularly since L. Weiskrantz, during a visit to this laboratory, had obtained experimental evidence that complete removal of striate cortex in the experimental monkey might be compatible with the return of more than flux perception, i.e., the operated animal can apparently distinguish a "speckled" field from any shade of gray (Weiskrantz, 1963). In an exploratory study, G. Wasserman has demonstrated that a patient with a large (perimetrically defined) homonymous scotoma can discriminate reliably between certain classes of stimuli, such as "closed" and "broken" patterns, when the stimuli were presented within the scotoma, under conditions of dark adaptation and brief exposure. These studies will continue.

(c) Evoked Potential Studies in Man with Normal and Abnormal Sensory Status In attempts at extending such studies of residual sensory function after destructive lesion of central representations, we have begun a systematic effort at exploiting averaging devices for the recording of evoked potentials in conscious man, including patients with various sensory disorders (scotomata, somatosensory defects) arising from penetrating wounds of the brain. Work on the visual evoked response of man (VER) has progressed most rapidly. This work is in the hands of Dr. Herbert Vaughan, assisted by R. Hull. Preliminary work on somatosensory evoked responses (SER) is still hampered by surprisingly large amounts of scalp and neck muscle artifacts. By contrast, the visual evoked response (VER) is definitely sensitive to cerebral lesions producing changes of the visual field (hemianopia, hemiamblyopia, sector scotoma), so that the method of averaging evoked responses holds promise for the development of an objective form of perimetry.

In addition, and in line with previous plans, a parametric study is in progress relating various aspects of the normal VER to stimulus variables, such as duration of a light flash, its energy, the visual angle subtended, and monocular or binocular exposure. More recently, these studies have been extended to investigation of timing of successive flashes in a pair, leading to perceptual interference, such as "monoptic" or "dichoptic" masking of the perception of one flash (or pattern) by the exposure of a second flash (or pattern) within a critical interval after the first.

It has been established during the last few months that the normal VER does reflect faithfully most or all of these variations in stimulus parameters. Moreover, the VER can be employed to yield psychophysical functions such as Stevens' brightness function, Bloch's law, and the Broca-Sulzer effect.

Stimuli have been presented by an electronic six-channel tachistoscope under conditions of dark adaptation. Intensity has been varied from 0.2 microlamberts to 0.2 lambert in 1/2-log increments. Duration varied from 100 microseconds to 500 milliseconds. A stimulus area of 4^{o} has been employed for most determinations, with a $1^{o}22'$ stimulus for analysis of foveal response. Electrical activity has been recorded from the scalp over the occipital area and average responses to 200 or 400 stimuli computed.

The following preliminary results have been obtained:

1. A characteristic VER is recorded for each stimulus condition.

2. Responses are reliably recorded to absolute threshold.

3. Latency of the major deflections of the VER provides a reliable index of stimulus conditions.

4. Latency of each wave is systematically related to that of the preceding wave as stimulus intensity (or energy) is varied.

5. A photopic (short latency) and scotopic (long latency) system have been identified. Intensity at which shifts from P to S occur agrees with psychophysical estimates.

6. Only short-latency responses are seen with foveal stimulation.

7. For stimuli of 10 msec. or less, Bloch's law is obeyed (i.e., for equal-energy stimuli, Ixt = c, VER is identical).

8. For long stimuli (100 msec.) intensity, and for short stimuli (less than 10 msec.) energy is related to VER latency by the equation $L = I^{m} + L_{o}$, where L = latency of a specific wave of the VER, I = intensity (or alternatively for brief stimuli, E = Ixt), M = a constant (-.33 for the initial positive wave of the VER), and L_{o} = minimum latency of the component of the VER under consideration. It is of interest to note that the form of the equation is that proposed by Stevens for perceived stimulus magnitude.

9. The effect of Broca and Sulzer appears to be represented in the VER by the occurrence of a minimum latency for stimuli of moderate intensity (i.e., 2 mlam.) for stimulus duration of 30-50 msec. Minimum latencies for more intense stimuli are found with correspondingly shorter stimulus durations.

The observations encourage further efforts at employing the VER as an index of gross spatiotemporal configurations of cortical neural response to photic stimulation. Initial steps take the following direction: Preliminary observation of response to patterned stimuli varied in contour length but constant in luminous flux and extensity of retinal stimulation. Substantial differences in form of response are obtained as a function of "contouredness." It also appears that the predominant response occurs not to total change in intensity but rather to onset of that portion of the stimulus configuration subjectively considered to be "figure" as opposed to "ground."

(d) Sensory Status of Adults with Basal Ganglia Lesions, Before and After Surgical Destruction of Thalamic Nuclei. During the period under review, Proctor et al. (1963) have published results of extensive studies of sensory functions in man before and after certain thalamic lesions aimed at the ventrolateral nuclear complex. These studies confirmed the classical view that there is no demonstrable sensory defect in uncomplicated basal-ganglia disease in man. However, after chemosurgery aimed at the ventrolateral region of the thalamus, a subtle and transient, yet characteristic sensory loss, was recorded on tests of two-point discrimination. After unilateral thalamic destruction in the right hemisphere, the contralateral hand showed defective two-point discrimination; after unilateral thalamic destruction in other patients, in the left hemisphere, both contralateral and ipsilateral hands showed such a sensory change. These results amount to an experimental confirmation of the earlier report by Semmes et al. from this laboratory (1960) who had found that gunshot wounds implicating the sensory representations in the right hemisphere produced merely contralateral sensory deficit, while similar gunshot wounds of the left hemisphere often produced deficits involving both hands. (Proctor et al., 1963)

2. New Studies of Children with Early Brain Injury (T. E. Twitchell, Maria Wyke, Ann Schiller, H.-L. Teuber). The studies just reviewed illustrate some of the unforeseen complexities of functional specialization between man's left and right cerebral hemispheres. According to traditional views, the principal and perhaps only difference between the hemispheres is seen in the selective role of the left hemisphere, in most adults, for the mediation of language functions. Yet the data just cited indicate that even sensory function may be differently represented in the two hemispheres, and there is increasing evidence, particularly from the work of Dr. Brenda Milner in Montreal, that right-hemisphere lesions in adults - while leaving language intact - might produce alterations in other functions (especially those involved in complex visual and visuomotor tasks), in a way not encountered after lesions to the left cerebral hemisphere. What is not clear is whether these differences in right and left hemisphere function are predetermined by the structural maturation of the brain, or whether function as such, e.g., the acquisition of language, might gradually produce these differences. The question might be answered by comparing the relative roles of right and left hemisphere lesions in adults to those in children with unilateral brain lesions sustained at birth or soon afterward. To this end, we have selected a group of 22 brain-injured children: 11 of these have congenital left hemiparesis, and the other 11, right. These children have undergone detailed neurologic examinations to determine whether their symptoms are strictly unilateral. The procedure employed in these special neurologic examinations will be described in the future. At present, each of these children is called for an intensive series of additional tests, including the following:

(a) Tasks involving detection of mixed and hidden figures. As we had shown earlier (Teuber and Rudel, 1962), early brain injury appears to manifest itself particularly on those tasks which in the brain-injured adult tend to disclose "general" (nonspecific) signs of cerebral lesions, notably on embedded-figure tests. These tests are now being applied to brain-injured children with right- and left-sided involvement of the body, in an attempt at detecting possible differences in effect of left vs. right-sided lesions.

(b) Field-of-search test. A remarkably sensitive sign of early brain injury in children seems to be defective performance on tasks involving active searching for visually presented objects in a complex array. Procedures are planned for continuous recording of the mode of searching, since earlier work on adults with frontal lesions had suggested particular patterns in which the search process appears to break down (Teuber, 1964).

(c) Body-scheme tests. Earlier work with brain-injured adults disclosed several specific changes in orientation to the body and to external space, especially after certain parietal-lobe lesions. An analogous task has been pretested in normal children of different ages by Dr. Rita Rudel (see below), and the results provide norms for our current testing of children with early brain injury in the right or left cerebral hemisphere.

(d) Intermodal transfer of shape discriminations. Lastly, work with brain-injured children is employing another task recently pretested on normal children - a task involving crossmodal transfer of shape discrimination (Rudel and Teuber, 1964, in press). These tasks involve presentation of tridimensional objects to the child, who has to identify each object among an array of objects presented either in the same sensory modality (vision or touch) or across sense modalities (from touch to vision, or from vision to touch). Preliminary findings indicate that in normal children crossmodal transfer on such tasks is not necessarily more difficult than intramodal transfer in the less efficient modality (touch to touch). If the brain-injured children show symptoms corresponding to those previously found in this laboratory in adults with parietal-lobe lesions, one should expect a selective and disproportionate impairment for transfer across sense modalities (Wyke, in preparation).

B. Studies in Experimental Animals

1. Ablation Experiments. During the period covered by this report, several studies have been in progress exploring effects of lesions in neocortex and allocortex, and in certain subcortical nuclei (dorsomedial thalamus, caudate nucleus), in rats, cats and monkeys. Two of these studies will be described:

(a) Effects of caudate and hippocampal lesions in the rat (S. L. Chorover and C. G. Gross, assisted by graduate student, S. Cohen). In the monkey, and possibly in man, caudate lesions can be shown to have behavioral consequences similar to those seen after destruction of frontal cortex. A recently published study by Chorover and Gross (1963) extends this observation to the rat. In this animal, bilateral lesions within the caudate nucleus produced clear and lasting impairment in acquisition and retention of a spatial alternation task. That this effect was a specific one was demonstrated by the essentially normal performance of these animals in an open-field maze. Conversely, bilateral lesions of posterior neocortex led to the classical impairment in an open-field maze but left the spatial alternation pattern intact. This study by Drs. Chorover and Gross thus represents a particularly clear instance of "double dissociation of symptoms." In an analogous study of bilateral hippocampal lesions in the rat (Chorover, Gross and Cohen, in preparation), essentially similar results were obtained: this allocortical destruction led to marked impairment of alternation performance, but again left performance in open-field mazes unimpaired. There are also indications that dorsomedial thalamic lesions in the rat may produce alternation deficits similar to those seen after caudate and hippocampal lesions. Further work on the caudate syndrome suggests that the impairment may involve performance on tasks requiring active avoidance, while passive avoidance shows little or no deficit (Gross and Chorover, in preparation). In all these respects, the functional organization of the rodent brain turns out to be quite similar to that of carnivore and primate.

(b) Comparison of orbitofrontal with anterior temporal lesions in the monkey (Helen Mahut). In these experiments, 6 monkeys (macaca mulatta) with removals from the orbitofrontal cortex are contrasted with 4 other monkeys with lesions aimed at the amygdalo-hippocampal region and with 4 unoperated controls. All of these animals have undergone extensive testing on visual discrimination tasks involving brightness, color and pattern, delayed alternation (with 5 sec. delays), spatial reversal of learning sets, object quality discriminations, and object quality discrimination learning sets. So far this extensive program of testing has revealed similarities rather than differences in the behavioral effects of orbitofrontal vs. amygdalo-hippocampal lesions. Such similarities of symptoms may not be unreasonable in view

of the presumed anatomical relations between the structures in question. However, efforts will be made to define tasks that might dissociate the effects of the two kinds of lesion. (For previous related work, see Mahut and Cordeau, 1963.)

2. Stimulation Experiments

(a) Behavioral effects of caudate stimulation in the cat (graduate students Elizabeth Burdash and M. Potegal, supervised by Professor C. Gross). In this project, multilead electrodes were implanted in the cat's caudate nucleus to permit study of effects of caudate stimulation in the unanesthetized animal during various learning tasks. High frequency stimulation was found to have no effect on learning or retention of the tasks employed, but low frequency stimulation seemed to have effects on behavior, possibly specific to locus of stimulation and to type of task.

(b) Studies of retrograde amnesia for a task learned in a single trial (S. L. Chorover and P. H. Schiller, assisted by graduate student D. Peterson). A series of experiments (recently summarized by S. L. Chorover at the International Conference on Memory Mechanisms at Princeton, N.J., September, 1963) may have provided means for resolving the conflict between those interpretations of retrograde amnesia which invoke the concept of trace consolidation and those which stress the aversive properties of the amnesia-producing agents. Drs. Chorover and Schiller have trained rats in a single trial to avoid stepping down from a raised platform onto an electrified grid. Electroshock convulsions, administered 5 sec. or less following the learning trial, produced clearcut erasure of the memory trace. However, contrary to expectations based on the usual form of the consolidation hypothesis, such retrograde amnesia fails to appear if the shock is delayed for 10 sec. or more. With these longer delays, the aversive properties of the shock become increasingly evident. The work has thus led to a reformulation of the consolidation hypothesis: apparently, primary memory consolidation is a much more rapid process than heretofore believed. Experiments aimed at defining the role of chemical agents (such as nucleic acid antagonists) have to be redesigned to take these new findings into account.

(c) Further study of short-term memory: electrical stimulation of "nonspecific" thalamic nuclei during learning by cats (Helen Mahut, assisted by graduate student Eve Blye). Experiments are under preparation to replicate and extend an early observation by Dr. H. Mahut (1962, 1964) which had suggested different effects of thalamic stimulation in cats, depending on the timing of the stimulations relative to the learning trial: Such stimulation can be delivered either (1) immediately after response, in an object-discrimination task, (2) just prior to the response, or (3) during the choice (while the objects to be distinguished are in the animal's view but the response is prevented by means of a transparent screen). The earlier observations by Dr. Mahut had indicated that learning of the task was impaired when stimulation

occurred immediately after each choice, while identical stimulation during the response seemed to facilitate learning; stimulation immediately before each trial, however, had no demonstrable effect. The new series of experiments are designed to test the degree to which the effects of stimulation after the act of choice can be interpreted as a true interference with learning (rather than with the animal's disposition to eat, or with other motivational factors). In addition, attempts will be made to define the critical time interval during which retroactive effects on learning seem to be possible. Dr. Mahut will vary the interval between stimulus choice and intrathalamic stimulation from 1 sec. to 20 sec., and more; this should allow one to define the limits of the period during which the brain must be left undisturbed following a choice, so that learning can progress in normal fashion. Lastly, other sites for brain stimulation are being explored, particularly the caudate nucleus and brain stem reticular formation.

3. Electrical Recording

Search for Electrophysiologic Correlates of Various Forms of Learning (C. G. Gross and G. Gerstein). Ablation and stimulation experiments have made it abundantly clear that the two types of tasks - visual-discrimination learning and delayed alternation - are separately vulnerable to neocortical lesions in the monkey: Visual-discrimination learning is impaired by ablation (or stimulation) of inferolateral temporal cortex, and delayed alternation by ablation (or stimulation) of dorsolateral frontal cortex. It is therefore reasonable to assume that execution of these two tasks might somehow engage these two cortical foci differentially. So far, however, there is no direct indication of such differential activation of temporal and frontal cortex, as seen in ordinary electrical recordings. Drs. Gross and Gerstein are therefore studying the electric activity in dorsolateral frontal and in inferolateral temporal cortex through chronically implanted macroelectrodes in unanesthetized monkeys. Recordings from these sites are obtained and compared before, during and after performance of various learning tasks, and at different stages of acquisition of correct responses. The tasks include visual discrimination learning, discrimination reversal, and delayed alternation. The recordings are put on tape and processed by means of a LINC computer. These studies will be extended by combining the macroelectrode recordings with reversible cooling of one or another cerebral focus, or with electrical stimulation at the presumably critical sites.

Analogous recordings, with and without reversible ablation (by cooling or stimulation), are also obtained through microelectrodes.

4. Chemical Manipulation of the CNS (Dr. Joseph Altman, Mrs. Elizabeth Altman, Research Associate Gopal Das, and graduate student Donald Pfaff). During the half-year under review, Dr. Joseph Altman and his collaborators have continued their autoradiographic investigations of protein, RNA and DNA metabolism of the brain under normal, experimental and certain pathological conditions. From the technical point of view, they have succeeded during this year in standardizing their autoradiographic procedures for the purpose of quantitative evaluation of the autoradiograms obtained. This is accomplished by means of an assembled microdensitometer which permits reliable determination of autoradiographic grain density of single nerve cells or larger brain regions.

Using these improved techniques, they were able to map the grain density of different brain structures in the rats following administration of a labeled amino acid, which is interpreted to represent the differential rate of protein metabolism in these structures (Altman, 1963a). In an effort to determine possible alterations in protein metabolism as a consequence of behavioral "activation," they have injected resting control animals, and animals exercised in a motor-driven wheel with labeled amino acid. The results indicate a considerable increase in the amino acid utilization of single cells in motor and other brain structures, provided the injection is made during exercise; if the radiochemical is injected after exercise, no significant changes are obtained (Altman, 1963b).

In an effort to study DNA and RNA metabolism in the brains of cats, Drs. Altman and Chorover have injected tritiated thymidine, uracil and adenine intraventricularly. This procedure has been recommended as a suitable one for the distribution of various chemicals over the brain. However, their autoradiographic results showed that intraventricularly injected nucleotides diffuse very sluggishly from the site of injection, suggesting that the cerebrospinal fluid is not a vehicle for the uniform distribution of essential chemicals in the central nervous system (Altman and Chorover, 1964).

In extending earlier studies by J. Altman, indicative of apparent DNA turnover in cells of the nervous system, further evidence was obtained for the utilization of tritiated thymidine by glia cells in the brains of normal rats and cats. The uptake of thymidine-H^3 by occasional neurons of the cortex remains ambiguous, but the granule cells of the hippocampus show intensive DNA metabolism (Altman, 1963c). The investigation of this problem is further pursued in normal animals of different ages, in animals exposed to differential behavioral treatments (exercise, rearing in enriched environments), and in animals whose brain structures were surgically removed.

Lastly, efforts have begun to restudy the selective uptake of certain steroid hormones by specific brain sites, especially the uptake of estradiol in rats. This work too is in the hands of Dr. and Mrs. Altman, assisted by graduate student, Donald Pfaff. They hope to improve upon the earlier demonstration by Michaels of a fairly selective uptake in restricted hypothalamic regions. In preparation for the experiments, female rats are oviariectomized and given the usual hormone treatment to establish normal responses to estrogen. They will be injected, later on, with radioactive estradiol, given subcutaneously. The uptake of the labelled hormone in the brain will then be studied by radioautographic methods.

II. General Experimental Psychology (Studies in Perception, Sensorimotor Coordination, Memory, and Learning)

A. Perception and Coordination

1. Role of Active Movement in Maintenance of Sensorimotor Coordination (Professor R. Held and Dr. E. Efstathiou, assisted by graduate student, P. Ablanalp). Among the central problems in studies of perception and motor function are the questions about origin and maintenance of spatial orientation. Man's major sensory channels - those of sight, hearing, touch - continuously map the external world in such a way that there is a subjective middle, a right and left, an above and below. This accomplishment is often interpreted as a simple consequence of the topologic representation of receptor surfaces - retina, ears, skin, joints and musculature - into corresponding receiving areas within the central nervous system. Yet, the spatial projection of anatomical structures onto one another cannot by itself explain the spatial order of our perceptions.

In point of fact, current work in our laboratories has shown again that large acquired gaps in the projection systems (such as an injury to optic radiation or cortex) can leave the spatial organization of objects perceived essentially intact. Thus, the principal feature of spatial orientation lies not in such passive mapping of a stationary scene, but in the ability of the perceiver to handle the continuous transformations of the scene, while it moves relative to himself. The work of Professor Held and his collaborators is concerned with this problem. In earlier studies which have just been summarized in a feature article in Science (Held and Freedman, 1963), they have systematically exploited two complementary experimental techniques: the methods of rearrangement and disarrangement. In a typical rearrangement experiment, a normal adult wears prismatic spectacles which displace all objects seen by a constant amount, or he wears pseudophones which displace the apparent source of sounds in a consistent fashion. In disarrangement experiments, the relation between the perceiver and his environment changes at random; for instance, the observer wears spectacles with slowly rotating prisms which deform his surrounds in a manner unrelated to his bodily movement, or he wears earphones producing noise while he walks about.

Numerous experiments of the rearrangement type (i.e., consistent displacements) have demonstrated that active exploration of the environment by the perceiver is a prerequisite for readaptation: if the man wearing simple displacing spectacles walks about, actively, for one hour, considerable compensation for the apparent displacement of perceived objects occurs. By contrast, if he is pushed around in a wheelchair for the same period, and over the same path, passively, then no adaptation to the

rearrangement occurs. Apparently, the basis for successful reorganization of perceptual space can be identified: what is needed are active (self-produced) movements of the perceiver which are correlated with the consequent relative motions of the world around him. These relative object-motions differ under conditions of rearrangement, but remain correlated with the self-produced motions of the observer's body, in the same fashion as they had been under normal conditions. Professor Held and his coworkers assume therefore that the nervous system stores the signals it produces at the start of a given voluntary movement and compares the stored signal with the sensory feedback which results from the execution of the movement. Adaptation to rearrangement would then entail the resetting of these centrally stored correlations.

If this is so, then experiments involving disarrangement should lead to rather different results, as compared with rearrangement studies. Under disarrangement conditions, features are introduced which make for inconsistent relations between self-produced movements and their consequent sensory feedback. Thus, under one set of conditions, the observer wears rotating prisms which displace objects in varying directions over time, independently of how the observer moves. Such conditions of decorrelation lead to a temporary breakdown of spatial organization, and of sensorimotor coordination. Further experiments have shown that prolonged exposure to random stimulation (visual or auditory noise) may be analogous: staring at a noisy visual field (random scintillations) temporarily degrades motion perception; walking about while listening to noise in earphones temporarily degrades the accuracy of auditory localization. If the listener is kept motionless throughout the exposure to the noise, the degradation is minimized.

In their recent article in Science, Drs. Held and Freedman (1963) have suggested that certain conditions of space travel may be analogous to a disarrangement experiment: they predict that an astronaut moving about in his capsule under zero gravity conditions would show some decay in his sensorimotor coordination unless appropriate countermeasures are taken to prevent this.

In still more recent experiments, Professor Held and his group have tested the generality of their assumptions. Earlier descriptions of adaptation and rearrangement have often argued that the adaptation depends on the presence of certain geometric features in the environment. E.g., in one of the oldest demonstrations of prism effects, one employs prolonged inspection of objectively straight lines through prismatic goggles which make the lines appear subjectively curved. After some time, these lines appear straight; following removal of the prisms, objectively straight lines appear (transiently) to curve in a direction opposite to the preceding prismatic distortion.

Quite similar effects can be obtained by staring with the naked eye at a set of curved lines; after some time these lines appear less curved; subsequent fixation of straight lines will produce an impression of curvature in the opposite direction.

These effects have previously been interpreted as a form of normalization in which the presence of objectively straight lines is said to play a central role. Yet a recently published study shows that the presence of lines in the visual field is not a necessary condition for readaptation (Held and Rekosh, 1963). A special optical environment was prepared for inspection, covered with stationary dots in random distribution. The field thus contained no straight lines, nor did it permit the observation of curvatures, but a moving observer was always able to extract a nonrandom feature from this environment: Since the spots were fixed in space, the relative rates of their displacement on the retina, during self-produced bodily movements, were nonrandom and thus systematically changed by placing a prism in front of the eye of the moving observer. Before and after viewing the surround through the prism, the subject's perception of the straightness of a vertical line was tested by having him vary optically the curvature of a grating of bars until they appeared straight. Again, active and passive conditions of exposure were employed and only the active condition led to readaptation. The experiment showed that "visual space can be warped solely as a result of transforming the relation between self-produced movement and its concurrent sensory feedback" (see also Held, 1963).

In further work on the effects of disarrangement, particular attention is being paid to the ways in which decorrelated visual feedback might modify the precision of eye-hand coordination. Previous studies had shown that the introduction of a varying optical displacement of the hand, during prolonged viewing by the eye, results in degraded eye-hand coordination. In the current series of experiments, decorrelation is introduced closer to the motor end of the motor-visual feedback loop. Essentially, the procedure consists of applying external force counter to the force normally generated by the muscles of the arm. As a consequence, the normal relationship between output signals to the musculature of the arm and the consequent movement of the arm is disturbed. Results to date prove that this procedure does indeed produce degradation of coordination as evidenced by increased variability in accuracy of reaching for visible targets together with decreased adaptation to fixed power prisms. Control experiments run with closed eyes, but with conditions otherwise identical, show very slight changes and are consistent with the interpretation that the critical decorrelation occurs in the motor-visual feedback loop.

Several investigators (including Held and co-workers) have discovered that the shifts in eye-hand coordination - following viewing of the hand through a wedge prism -

transfer to localizing movements of the arm directed at spatially localizable stimulation given in nonvisual modalities (hearing, touch). One investigator (C. S. Harris: Adaptation to Displaced Vision: A Proprioceptive Change. Doctoral Dissertation, Harvard University, 1963) has proposed that this transfer results from change in the "felt" position of the hand in relation to the body, and that most of the effects of adaptation to visual rearrangement result from such proprioceptive changes. In the course of a series of experiments studying this crossmodal transfer, Professor Held and his co-workers have shown that the interpretation of these transfer effects in terms of a purely proprioceptive change is quite untenable. In one experiment, subjects were trained to reach for targets whose locations were known solely by their "felt" positions. After viewing the hand through a wedge prism, no shift of localization was found with this method of testing: a result which is inconsistent with the interpretation that the "felt" position of the hand with respect to the body is changed.

The crucial events in readaptation thus are neither restricted to sensory systems alone, nor to motor systems alone, but entail an interaction between the two (see, also Mikaelian and Held, in press). These interpretations are quite consistent with the ways in which space perception breaks down in the presence of cerebral lesions (see Section I of this report and Teuber, 1963), and with the comparative and developmental studies that will be described below (Section III).

2. Illusions - Visual and Haptic (Drs. Rudel, Schiller and Teuber). The problem of interaction between sensory modalities continues to engage the attention of our laboratories. Under ordinary circumstances objects seen are readily identified with the same object felt, but the mechanisms underlying such crossmodal equivalence is at issue. A considerable body of evidence has been invoked to suggest that such intersensory transfer is always indirect, learned, and often verbally mediated. Such claims suggest that crossmodal tasks should be explored in children (see below, Section III); in working with adults, the tasks of choice would be those that are likely to be nonverbal, so that the perceiver should not be able to transfer information from one sense modality to the other simply by attaching the same or similar words to the objects in question.

Tasks of this sort are notoriously difficult to come by; a possible attack is one that employs the classical geometric illusions. Thus, the so-called "Müller-Lyer" illusion (<——<——>) can be shown to occur to nearly equal degree in vision and touch. In a recently published study (Rudel and Teuber, 1963), we have shown that the illusion shows a progressive decrease in extent, on repeated trials, in either sense modality, visual or tactual. Since this decrement occurs without any

awareness on the part of the perceiver, it seems to be a suitable effect for tests of intermodal transfer. It has in fact been possible to demonstrate that the decrement transfers quite readily from a series of visual presentations of the illusion to a series of haptic trials, and vice versa. What is more, the transfer effect is asymmetric and definitely so: the extent of the decrement that carries over from touch to vision significantly exceeds that found on going from vision to touch (Rudel and Teuber, loc. cit.). This asymmetry of crossmodal transfer is analogous to earlier findings from these laboratories, particularly to studies by Dr. Josephine Semmes (Semmes et al., 1954) and by Dr. George Krauthamer (1959). However, in those earlier studies, verbal mediation of transfer effects was not as unlikely as in the present experiment which suggests to us a direct crossmodal effect. The positive results in the present study are all the more surprising in view of the recurrent suspicion that the visual and tactile forms of the geometric illusions may involve somewhat different underlying mechanisms, a possibility being explored, currently, by Dr. Peter H. Schiller.

3. Anisotropies of Visual Space (Visiting Professor H. Leibowitz, assisted by graduate student S. I. Shapiro from Pennsylvania State University). The observations on decrement in the Müller-Lyer illusion, and on transfer of this decrement across sense modalities, do not in themselves yield any clues about the origin of the illusion as such. This persistent problem might be attacked from either of two directions. First, one can explore the old hypothesis that illusions are constancies misapplied (see Teuber, 1960), and secondly, one may attempt to relate the illusion effects to the recent disclosures by Hubel and Wiesel (D. H. Hubel and T. N. Wiesel: Receptive fields of single neurons in the cat's striate cortex. J. Physiol., 1959, 148, 574-591.) about the processing of visual information in cortical receptor fields. In this latter connection, it may be well to reinvestigate some of the old claims about anisotropies of the visual field, e.g., the differential sensitivity to seen movement, depending on the direction of the movement across the retina. A beginning was made by Dr. H. Leibowitz, who spent two months in our laboratories during the summer of 1963, as visiting investigator from Pennsylvania State University. Assisted by S. I. Shapiro, he reinvestigated the role of orientation of lines in the visual field in determining angular discrimination; he was able to confirm the existence of definite maxima and minima for the estimation of angles formed by two intersecting lines, depending on the orientation of the test lines in the subject's frontal plane.

In a related study, Dr. Leibowitz measured the rates of disappearance of a

stationary line on prolonged fixation. He noted that such a line disappears faster in oblique than in horizontal and vertical orientations. These systematic asymmetries of function in the visual system cannot be assimilated to any existing theory, but any adequate theory will have to comprise them.

Additional work by Professor Leibowitz during his visit has dealt with the perceptual response to color fringes produced by wedge prisms. Prolonged wearing of such prisms leads to a gradual disappearance of such color fringes, which briefly reappear, in reverse spatial order, as soon as the wearer removes the prisms and looks at contours with the naked eye. An earlier (unpublished) study by R. Held had suggested that the rate of disappearance of such color fringes during prolonged wearing of prisms might be greater under active than passive conditions of observation.

Professor Leibowitz has investigated this possibility further by studying rates of adaptation in pairs of observers; one observer in each pair, while wearing the prismatic spectacles, threw darts at a dart board with black and white vertical stripes, while the other, wearing identical goggles, kept score but did not actively throw the darts. Rate of disappearance of the color fringes was measured by means of a viewing box with a black and white grating; in a brief series of trials, the subjects adjusted the intensity of illumination in this box so that the colored fringes became just barely visible (ascending trials) or invisible (descending trials). The results showed a considerable increase in the rate of disappearance of color fringes during the more active exposure (dart throwing) as compared with the less active (score-keeping) condition. Furthermore, there are preliminary results suggesting that children adapt faster to the color fringes than adults, but more observations on this point are needed.

4. Studies of Perceptual Blanking and Metacontrast (Dr. P. H. Schiller). Short-term interaction between successive visual stimuli has been known for over a century. Yet the essential mechanisms remain unexplained. A careful delineation of these perceptual effects is particularly urgent because of the recent development of evoked potential techniques (see above, Section I) which permits the monitoring of electrical events in the human visual system during the performance of these perceptual tasks. In a series of studies (most of which are still in progress), Dr. Peter Schiller is attempting to define and distinguish those visual phenomena in the normal adult which are designated as "perceptual blanking" and as "metacontrast." Dr. Schiller has recently reviewed the reason why, in his opinion, these two terms should be distinguished: In a typical instance of perceptual blanking, the perception of an information-bearing stimulus pattern is obliterated, if another pattern (or a

blank field) overlapping the same area of the retina is made to follow the first pattern within a critical time interval. In effects that should be called "metacontrast," the interacting patterns are adjacent in the field; for instance, three dark rectangles are made to appear in a row for 10 milliseconds; if the center rectangle is displayed just prior to the two flanking rectangles, it can be made to appear gray, or disappear altogether; the usual maximum of the effect occurring with 100-millisecond delay (Schiller, in preparation). Failure to distinguish blanking from metacontrast has probably added to the controversy about these effects. It should be obvious that spatial separation would interact with temporal separation of successive visual stimuli in certain definite ways.

Another intriguing question about these phenomena concerns the relative roles of monocular and binocular exposures. Earlier work had indicated that many metacontrast phenomena are still observed, if the first stimulus pattern goes to one eye, and the second pattern to the other. Yet there are recent reports disclaiming such binocular effects. Several experiments by Dr. Schiller seem to clarify these issues: Perceptual blanking (i.e., obliteration of momentary patterns by a nonfigured flash following afterwards) is found only on presenting both stimuli to the same eye. However, if the second stimulus itself contains contours, it can exert effects from one eye to the other, depending on the state of the observer. At the onset of a series of trials, a naïve observer will obtain marked effects from eye to eye: a figured flash given to the second eye will wipe out whatever information had been given to the first. Quite unexpectedly, however, the situation changes as the number of trials is increased. With "practice" the observer begins to dissociate the two eyes and reports both patterns, even though he may be totally unaware of the fact that he is learning to "uncouple" his two eyes in this particular setting. Such practice effects are less marked if the two successive stimuli impinge upon one and the same eye (Schiller, 1964; Schiller and Wiener, 1963).

5. Studies on Color Vision (graduate students W. A. Richards and G. S. Wasserman). The role of spatial and temporal interaction in vision is at least as important in the perception of color as it is in that of brightness and form (see above). Yet a great deal of the classical work on color vision has employed small isolated patches of light from different parts of the spectrum, and used long exposures. It took the studies of Hurvich and Jameson on spatial interaction and the dramatic demonstrations by Edwin Land to create a more general awareness of the fact that simultaneous color contrast is not a mere disturbing admixture to basic color processes, but may well be an essential mechanism of color perception. Similarly, the electrophysiologic studies by Svaetichin and others have stressed again the lability of color-receptor systems in time and suggest an experimental exploitation

of the color effects of monochromatic light flashes of varying (short) durations.

The latter approach has been chosen by Mr. Gerald S. Wasserman for his doctoral dissertation, in which he investigates the apparent hue of brief flashes of different monochromatic lights, and the apparent brightness of single and repetitive flashes. He expects to find that the familiar enhancement of brightness, in flashing light, will have different maxima, depending on the spectral location of the intermittent stimuli. If successful, these results should bear quite directly on color theory and yield practical suggestions for physiologic experiments.

In a somewhat similar study done in collaboration with the U.S. Naval Research Laboratory at Groton, Conn., Mr. Whitman A. Richards (another graduate student in our laboratories) has obtained color-mixture functions at low luminance levels. The calculations involved in the analysis of the color-matching functions were performed on the IBM 7090 computer at M.I.T.'s Computation Center. To cite the results from the summary of a forthcoming paper (Richards and Luria, submitted for publication, 1964).

"As the luminance is decreased, the foveal luminosity functions obtained with a 2^{o} field remain almost invariant, but large changes take place in the color-matching functions. In spite of these changes, however, photometric additivity expressed in the form of Abney's Law appears to be approximately valid at all luminance levels, while chromatic additivity seriously fails at the low luminance levels. In the parafovea, both the luminosity and color-matching functions change as the luminance is decreased, and the changes in the latter are almost identical to those occurring in in the fovea. All of these changes are of the form expected from increased effects of rhodopsin, if the rhodopsin is confined primarily to one type of receptor."

"Two independent methods of analysis of the color-matching data confirm the hypothesis that the effects of rhodopsin are limited primarily to one receptor whose fundamental response function at photopic levels is approximated by Pitt's 'blue' fundamental. The changes in this blue response function are as if there is a conversion of the photopic blue pigment to rhodopsin, producing a mixture of the photopic pigment and rhodopsin in the mesopic region. This result, together with the similarity of the changes to those which occur in luminosity functions obtained in a peripheral region highly populated with rods, suggests that the rods are the blue receptors. If this is the case, then the blue photopic pigment would probably be acid indicator yellow, which is derived from rhodopsin during light adaptation, accompanied by a simultaneous decrease in pH in the receptors."

6. Time Perception (Graduate student, W. A. Richards). In spite of the current revival of interest in temporal factors in visual perception, there still is very little work on the perception of time itself. The lack of such work is all the more surprising in view of the steadily increasing concern with circadian or other rhythms in lower forms of life and the possible exploitation of biosatellites for the study of these rhythms. In a recent term project, Mr. Richards has obtained estimates of brief time intervals from normal adults and children; he has analyzed these estimates, obtained by a method of reproduction, by searching for those objectively measured time intervals for which the error of reproduction was minimal. For all subjects, there were several such time intervals which were reproduced most exactly, and these times could be shown to be 2^n times 1.5 seconds (where n has integer values). These studies will probably be resumed in order to explore the possible development of capacity, in children, for time estimates of this type, and the further possibility of changes in the apparent underlying cycle as a function of different physiologic states. Thus the analysis suggests new ways of assessing the effects of drugs on time perception, or of measuring distortions in time perception following prolonged exposure to unstructured (noisy) environments.

B. Memory, Learning, and Thought

1. Recent Memory (Verbal Learning Studies) (Dr. W. A. Wickelgren). More than sixty years ago, Ranschburg published observations on a peculiar form of "inhibition" in perception (recognition), and recall: A series of items (e.g., numbers) were projected simultaneously for 0.3 seconds on a screen; if one of the items occurred more than once, both recognition and recall of the total series were hampered (Ranschburg inhibition). In a recent study, Dr. Wickelgren (1964a) has re-examined this curious phenomenon, with one important difference in method: Instead of presenting all items at once, they are given successively at various rates, and the subject's task is to reproduce the items immediately afterwards, The data are then scored for both ordered recall and free recall. Under either method of scoring, recall is sometimes hampered and sometimes improved by the insertion of repeated items. Specifically (and contrary to Ranschburg's general statement), short-term memory can be helped by the presence of repeated items in a run of items, especially if (a) the repetition occurs in runs of three (rather than two), (b) if fewer items separate the occurrence of repeated items, and (c) if the repetitions occur near the beginning of the sequence (rather than its middle or end).

From these and similar observations, Dr. Wickelgren concludes that facilitation of recall (instead of the more usual inhibition) tends to occur under those conditions which favor the recoding of a run into a single chunk (e.g., three times the number 8, at the beginning of a run such as 888 217 549). Conversely, inhibition (worse recall) is found whenever conditions are presumed to be unfavorable for recognizing the repetition (e.g., the repeated items are widely separated in the sequence), so that recoding of the sequence into fewer chunks is hampered.

These findings are discussed by Dr. Wickelgren in terms of an associative theory of recent memory, together with the assumption that there is a recoding mechanism for recent memory, just as had been assumed for long-term memory in the past.

Additional experiments explore the role of rates of presentation of items in short-term recall, confirming the presence of inhibitory and facilitatory effects under conditions permitting silent rehearsal, and under conditions giving minimal opportunity for such rehearsal. Furthermore, the role of grouping of items for their subsequent recall was investigated by instructing the subject to rehearse them silently in groups of 1, 2, 3, 4, or 5 digits (Wickelgren, 1964b). The results of this particular experiment supported the hypothesis that only three serial position concepts (beginning, middle, and end) are important cues in short-term memory.

2. Studies of Logic and Syntax (Graduate student Preston B. Rowe, Jr., supervised by Dr. W. Wickelgren). The fundamental work of the linguist N. Chomsky at M.I.T. on syntactive structures has opened the way for reinvestigating the central issues in the psychology of language and thought. Specifically, it has become possible to study in a rigorous fashion the relations between the logical content and the syntactic structure of sentences. Preston B. Rowe, Jr., supervised by Dr. W. Wickelgren, has begun such experiments: a series of syllogisms is presented to a number of listeners who are asked to judge the logical validity of these syllogisms. By manipulating the content of the syllogisms and (independently), their syntactic structure, judgments of logical validity can be improved or impaired in a systematic manner. In the near future, analogous studies will be done with children of different ages.

3. Further Effects of Syntactic Structure (Dr. J. Fodor, Mr. T. Bever). A number of years ago, Broadbent described a curious phenomenon: A sentence is being played on tape and a single click is put at some point of time into the sentence; under such conditions a listener shows considerable errors in judging where the click has appeared in relation to the sentence. One might predict that such errors might be influenced by manipulating the syntactic structure of the sentence. Earlier experiments of this sort led to conflicting results, possibly because of peculiarities of method (e.g., the judges had a printed version of the test-sentence before them, instead of merely listening to the tapes). Dr. J. Fodor and graduate student T. Bever have recently resumed work on this phenomenon; their preliminary results suggest that the error in judging the temporal position of the click is nonrandom; most listeners tend to displace the click toward the nearest syntactic junction point. If this effect should prove to be sufficiently dependable in adults, similar tests will be run with children at various stages of language development.

III. Studies in Developmental and Comparative Psychology

A. Developmental Studies

1. Effects of Early Experience on Sensorimotor Development in Human Infants (Dr. Burton L. White, Principal Investigator; Professor Richard Held, Project Director; Miss Kitty Riley, Research Assistant). During the first six months of life, the human infant develops an astounding range of sensorimotor capacities, including the ability to turn his gaze upon objects, to accommodate and converge his eyes, and to coordinate his hands and eyes in visually-guided reaching. It is usually assumed that these functions mature in an automatic fashion, and the normative studies of the Gesell laboratories have done much to reinforce this view of an endogenous growth process in which the environment plays only a minimal role.

By contrast, a good many recent studies suggest that the maintenance of normal perception and of sensorimotor coordination may depend critically upon the continuous presence of a structured environment and upon an orderly relation between self-produced movement of the perceiver and "reafferent" sensory feedback from the environment. Thus, normal adults can achieve complete readaptation to drastic changes in the usual output-input relations (as under the influence of prismatic spectacles or pseudophones), as long as they are permitted to move in a structured environment during the period of readaptation. In this way, rearrangement experiments suggest a far-reaching plasticity of adult coordination. Disarrangement experiments including exposure to random input or decorrelation between motor output and reafferent input (see above, Section II) lead to transient decline of sensorimotor coordinations.

Such plasticity at the adult level suggests but does not prove a similar degree of plasticity in early development. Professor Held and his co-workers assume that the same mechanisms which mediate adaptation under conditions of rearrangement are also involved in the initial acquisition of sensorimotor coordinations. Accordingly, they have begun a systematic reinvestigation of the origins of normal sensorimotor coordination in human infants.

Most of this work proceeds at a special nursery at Tewksbury, where the research group has access to infants reared under unusually uniform conditions amounting to chronic sensory deprivation. These infants are kept on their backs in uniformly painted cribs and rooms, receiving minimal handling (during feeding hours) from a small staff of nurses. Under such relatively stable conditions of rearing, the research group has obtained normative data on the time and order of appearance of various sensorimotor patterns: head turning, different eye movements, symmetric clasping of hands, hand-regard, "swiping" movements of hand, and other stages in the

emergence of visually directed reaching. After establishing these norms, the group has proceeded to introduce different forms of enrichment of the sensory environment in order to note whether such enrichment, at different stages, might influence the rate and course of sensorimotor development. Results obtained thus far show clearly that the emergence of various patterns of coordination can be markedly accelerated. Some forms of eye-hand coordination, for instance, can be made to appear six to eight weeks earlier than normally, in these infants, by the simple device of suspending mobiles (brightly patterned toys) above their cribs, or (even more) by attaching colored objects to the walls of the crib at either side of the infant's head. Not only the presence of such patterns, but the time of their introduction during the first few months may turn out to be critical.

An incidental outcome of these studies (which are still in progress) is the establishment of norms for the development of accommodation in the human infant. At birth, the accommodation mechanism of the human eye seems to be inoperative. By means of a modified type of streak retinoscopy, the emergence of accommodative capacity has been traced, showing that the level of performance of the normal adult is reached at the age of 3-1/2 months (see Held and Hein, 1963; White, 1963; White et al., in press).

2. Discrimination of Direction of Lines by Children (Drs. Rita G. Rudel and H.-L. Teuber). In working towards a theory of perception and perceptual development, much can be gained by noting those aspects of perception that are late to appear in ontogeny or phylogeny, or are selectively vulnerable to cerebral lesions. It has now been known for nearly seven years that the octopus shows a consistent tendency to confuse oblique lines on discrimination learning tests. Thus, the animal treats / and \ as equivalent, while being perfectly capable of distinguishing | from —. This confusion of obliques has now been shown to exist in an essentially similar fashion in normal children. In a recent publication by Rudel and Teuber (1963), persistent confusion of visually presented obliques was shown for four-year-old children who could distinguish verticals from horizontals with little or no error. This work is now being extended by Dr. Rudel to tactile presentation of directional stimuli.

3. Crossmodal Transfer of Sensory Information by Children of Different Ages (Drs. Rita G. Rudel and H.-L. Teuber). In earlier sections of this report, we have raised the question of why an object seen is so readily identified with that same object felt. We believe there is evidence for a direct crossmodal transfer of sensory information, a transfer which does not require mediation by verbal labels. Still, there are indications from previous work in these laboratories indicating that capacity

for transfer of this sort may be particularly vulnerable to parietal-lobe lesions in previously healthy adults, and that brain-injured children may show grave deficiencies in this respect. It thus becomes all the more urgent to trace the normal course of development of this capacity.

Accordingly, Drs. Rudel and Teuber have completed a study (1964), in which normal children, aged 2, 3, 4, and 5, were asked to identify various solid objects presented to them by sight or by touch, and then to re-identify these objects, in either of these two modalities. The experiment was so designed that accuracy of identification could be tested separately for a situation in which the child had to carry information (a) from one series of visual presentations to another visual series (intramodal transfer), (b) from visual to tactual presentations; (c) tactual to visual (crossmodal transfer), or, lastly (d) from a tactile to another tactile series (again, intramodal). If it were true, as has often been claimed, that crossmodal transfer should be intrinsically more difficult than intramodal transfer, then the situations involving touch as well as vision (b and c) should have yielded a performance inferior to that obtained on purely visual or purely tactile tasks (a and d). The results, however, were quite different: the visual-to-visual task turned out to be easiest, the tactual-to-tactual, hardest, with the other two tasks (tactual-visual, and visual-tactual) being intermediate in difficulty. These results were essentially the same at the different ages tested, and were thus independent of the overall proficiency of the children (which increased with increasing age). One can therefore conclude that crossmodal tasks do not necessarily pose difficulties in perception beyond those posed by intramodal transfer situations; moreover, the purely tactual (or "haptic") mode seems in and of itself less efficient for recognition and matching than the visual mode, regardless of the subject's age.

In a related experiment now in progress, Dr. Rudel is exploring crossmodal transfer for bisection of lines. The task involves repeated bisection of a horizontal line, presented to the children either visually or haptically.

The bisection is either accomplished by having the child or the experimenter move, alternately, a small metal marker from the extreme left or right end of a test line to its supposed midpoint. Under these conditions, children exhibit marked starting-position effects, that is, they tend to keep the marker too far to the left if a trial had been started from the left, and too far to the right if a trial started from the right. These starting-position errors have been observed previously by ourselves and others; the effects are a direct function of age, being the greater the younger the child. Early brain injury likewise enhances these errors, even in older children (Teuber and Rudel, 1962). What was not known is that these effects diminish

on repeated trials, an observation made only quite recently by Dr. Rudel. She is in process of exploiting this decrement in order to seek, in children, a possible transfer of this decrement (of starting-position errors) from repeated visual to tactual trials, and, conversely, from tactual to visual.

4. Development of Orientation to the Child's Own Body (Dr. Rita G. Rudel). Previous work on effects of parietal-lobe lesions in adults has confirmed the long established view that orientation to the body as well as orientation in surrounding space are selectively vulnerable to these lesions (for a recent summary, see Teuber, 1963). A task of bodily orientation had been developed in this connection by Drs. Semmes, Weinstein, and Ghent. This task is now being applied systematically by Dr. Rudel to normal children, 5, 6, and 7 years of age (and to corresponding groups of children with congenital brain damage by Dr. Maria Wyke). The task consists of showing the child a series of schematic drawings of the human body, on which different parts are marked. The child has to point to the corresponding portions of his own body. Some of the drawings depict the body as seen from the front, others as seen from the back, so that the task involves not only correct identification of body parts (including fingers), but also repeated reversal of right and left orientation. Errors of localization diminish with age, as expected, but they do so differentially for different types of errors: first to be overcome are errors in the identification of body parts, second are errors involving confusion of dorsal and volar aspects of the hands, and last to be overcome are errors of lateralization, i.e., for right and left sides of the body.

5. Children's Acquisition of Values; Studies in Social Influence (Dr. H. D. Saltzstein). After the pioneering studies by Piaget, comparatively little has been done to elucidate the ways in which children acquire social norms and moral values. The generalizations offered by Piaget suggest that young children show greater susceptibility to social influence than older children and adults; in fact, Piaget traces a progressive change from a heteronomous (other-directed) to an autonomous system of values, with advancing age. While ingenious, these interpretations require more stringent experimental tests than were provided in Piaget's laboratory. There is the further question of how persistent the effects of social influence might be, particularly in younger children. Conceivably, many of the differences between value judgments by children and adults might reduce to the evanescence of certain types of normative influence in young children.

In a recently initiated series of experiments, Dr. Saltzstein is testing social

influence in boys and girls ranging from 8 to 14 years of age. These children are shown a series of irregular dot patterns projected onto a screen and are asked to estimate the number of dots, either in the presence or absence of potentially distorting influence (e.g., a written note is passed to them, purportedly coming from a peer, suggesting an excessively high estimate.) The effects of such influence are tested for the stimulus display to which the influence note refers, and for subsequent stimuli. The spread of influence to these subsequent stimuli is tested in the presence or absence of peers, in order to check on extent, persistence and nature of the social influence, at different ages.

B. Studies in Comparative Psychology

1. Intra- and Interocular Transfer of Visual Training in the Goldfish (Dr. David Ingle). Under ordinary circumstances, the human adult can identify patterns no matter where they impinge on his retina, provided they fall onto areas of sufficient acuity. Similarly, there is immediate transfer of visual information from one eye to the other eye, or of tactile information from one hand to the opposite hand. The existence of such equivalence has been a central argument for those theories of perception which deny or minimize the role of specific connections in the nervous system, notably the views of Lashley and of the Gestalt psychologists.

It is only quite recently, under the impact of Sperry's work with split-brain preparations, that the limits of such transfer have been explored. Following transection of major commissures between the cerebral hemispheres, as well as sagittal section of the optic chiasma, cats and monkeys behave in some respects as if each eye were totally cut off from the other (R. W. Sperry: Cerebral organization and behavior. Science, 1961, 133, 1749-1757.)

Analogous studies can be done on lower vertebrates such as the goldfish, where the optic chiasma is completely crossed, and where the commissures between the two optic lobes have been shown to provide normally far less than perfect interocular transfer (R. A. McCleary: Type of response as a factor in interocular transfer in the fish. J. comp. physiol. Psychol., 1960, 53, 311-321; A. Schulte: Transfer and Transpositions - Versuche mit monokulär-dressierten Fischen. Z. vgl. Physiol., 1957, 39, 432-476.)

As Schulte and McCleary have shown, independently, there is definite interocular transfer of learned responses to patterns in the goldfish, but the extent of this transfer and, in fact, its appearance or failure to appear depend on the type of patterns employed, and on the response required. For instance, some forms of transfer can be detected only by cardiac conditioning methods: a goldfish trained to show active avoidance of electric shock by swimming forward as soon as a particular line pattern is shown to a monocularly trained eye, will fail to show this avoidance response when the same pattern is shown to the other (untrained) eye. Yet the same fish may exhibit a definite alteration in heart rate, on presentation of the "threatening" pattern to the untrained eye (McCleary, op. cit.).

Dr. David Ingle has recently extended the use of these techniques to experimental comparisons between intraretinal and interretinal transfer in the goldfish. Dr. Ingle's results indicate that certain pattern discriminations may actually

transfer somewhat better from one eye of the fish to homologous parts of the contralateral eye, and less well from the nasal to the temporal part of one and the same retina. Systematic variations in the patterns employed between training and transfer tests serve further to delineate extent and limitations of intra- and interocular transfer. Quite recently, Dr. Ingle has begun to experiment also with surgical interventions, involving transection of commissures between the two optic lobes of the goldfish. There are plans for still further extension of these methods to include temporary inactivation of part or all of an optic lobe, possibly in analogy to the techniques of Bures.

2. Novelty-Seeking in the Hamster (Graduate student G. E. Schneider) The role of novel stimuli in controlling animal behavior is in itself a rather novel type of investigation. Until quite recently, theories of motivation were based on an all but exclusive concern with elementary drives, and little attention was paid to the pervasive needs of animals for variations in their sensory experience. Studies of habituation and arousal and of their electrophysiologic correlates have suggested that stimulus patterns have central residues ("models") against which new inputs are matched; "unexpected" stimuli produce arousal by virtue of their discrepancy from these central models (S. Sharpless and H. Jasper: Habituation of the arousal reaction. Brain, 1956, 79, 655-680; E. N. Sokolov: "Neuronal Models and the Orienting Reflex," in Mary A. B. Brazier (ed.). The Central Nervous System and Behavior. Josiah Macy, Jr. Foundation, 1960, pp. 187-276).

In a recent unpublished paper, G. Schneider, one of our graduate students, has suggested that active exploration of the environment continuously both produces and reduces the mismatch signals arising from observed discrepancies between central residues and continously new inputs into the nervous system. Novelty-seeking behavior of this sort (or by a more simple name, curiosity) has been attributed primarily to monkeys and apes, and to some of the aquatic mammals. In a series of simple experiments, G. Schneider has shown a similar role of curiosity in the control of behavior in hamsters. For instance, he was able to show that hamsters would traverse an alley without food or water reward, and without shock avoidance, merely to make contact with various small toys placed at the end of the alley; if the same toys were kept on repeated trials, the latencies of traversing the alley were longer than when new toys appeared on each run.

3. Early Stages in Visuo-Spatial Organization of Perception in Young Kittens (Dr. A. Hein, assisted by Ellen Carol Gower). When young carnivores or primates are raised in darkness or diffuse light, normal pattern perception fails to appear.

These observations are usually interpreted as showing that early experience with visual patterns (learning) is a necessary condition of normal perceptual development. Yet interpretations of this sort are rendered ambiguous by the increasing evidence for actual histologic and electrophysiologic abnormalities in the higher visual pathways of such "deprived" animals. Thus, Hubel and Wiesel have shown quite recently that the various visual receptor fields with their sensitivity to different types of stimulus patterns can be identified immediately upon the opening of the eyes in very young kittens. If one eye, however, is kept closed (by suturing the lids together), the central receptor fields corresponding to that eye disappear, in analogy to an atrophy of disuse. Such results suggest that the presence of visible contours in early youth - while required to maintain a normal visual mechanism - are perhaps not needed to establish it in the first place. To decide the issue, a condition of rearing has to be discovered which avoids the production of atrophy in the animal's visual system.

A recently published experiment by Held and Hein (1963) seems to provide such a test situation. Newborn kittens were raised in darkness, except for a daily one-hour exposure in the light. During this hour, pairs of kittens were exposed to visual patterns inside a drum, in such a way that one kitten walked about actively, while the other kitten (from the same litter) was carried about by the first, in a little cart, so that his visual experience was obtained passively. Under these contrasting conditions, the "active" kitten shows normal visually-guided placing responses, normal avoidance of an apparent drop-off on the "visual cliff" test (R. D. Walk and E. J. Gibson: A comparative and analytical study of visual depth perception. Psychol. Monogr., 1961, 75(15, Whole No.519), and normal pattern discrimination learning. The passive kitten, however, exhibits nothing but reactions to different degrees of luminance. These results suggest that opportunity for correlating self-produced movements with the corresponding reafferent feedback may be a necessary condition for normal visuomotor development.

In a further, more recent experiment in this series, kittens were reared in darkness as before, but their daily exposure to patterns was given with one eye blindfolded. Following exposure, the blindfold of each kitten was shifted to the opposite eye, and the conditions of visual training reversed, so that each kitten had one active and one passive eye. The results confirmed those of the earlier study in a striking way: each kitten had one eye (the "active" eye) which possessed normal pattern perception, while the other eye (the "passive" eye) was form-blind, at least in terms of the behavioral tests employed.

One of these kittens, in which the differential training of the two eyes had been continued for over five months, was then taken to the laboratory of Drs. Hubel and Wiesel, and its cortical receptor fields were mapped in an acute experiment with separate visual stimulation of either eye. In contrast to the abnormal findings obtained after rearing in diffuse light, cortical receptor fields obtained by stimulation of either eye were entirely normal, suggesting that the presumed interaction between self-produced motor output and sensory input involves levels of the nervous system beyond the visual cortex.

4. Comparison of Capacity for Intertrial Transfer (Formation of Learning Sets) in Tupaia (tree shrew), stumptail Macaque, and Rhesus monkey (Dr. C. G. Gross, assisted by graduate student G. Schneider and by Misses Cooper and Norris)

The variety of forms within the order of primates provides particular opportunities for correlative studies of brain structure and behavior. Some of the prosimians (such as the lorises and tarsiers) have considerably less differentiated brains than the Rhesus monkey, or the anthropoid apes, so that it becomes possible to gauge the extent to which differences in cerebral structure are correlated with differences in behavioral repertoires. It would seem to be a task of particular promise to extend such comparisons further downward by including transitional forms, such as the tree shrews (Tupaia), a group recently elevated by some taxonomists to the status of primitive primates.

We have been able to obtain a small colony of Tupaia glis from Malaya and to keep these rather unusual animals "healthy and happy" (Dr. C. Gross). In addition to numerous naturalistic observations on their behavior (G. Schneider, guided by Dr. Gross), efforts are being made to breed these animals, despite the notorious cannibalism shown by captive female Tupaias toward their offspring. One young Tupaia, born in the laboratory, was separated from its mother and hand-raised until its death at the age of 30 days. We expect additional births and greater success in raising the young, particularly since the first attempt at raising these animals in our laboratory has yielded guidelines for the proper handling and feeding of the young.

Formal testing in experimental settings has thus far been restricted to comparative studies on the acquisition of object discrimination learning-sets by Tupaia, squirrel monkeys, stumptail Macaques (Macaca speciosa), and Rhesus monkeys (Macaca mulatta). The work, which is still in progress, entails presentation of a pair of objects for six consecutive trials. A reward is hidden under one of the objects, and the animal has to detect which of the objects signifies

the reward. After six trials, a new pair of objects is substituted for the previous pair; again, one of the objects hides a reward. The procedure - continued over hundreds of such blocks of six trials - permits one to assess the tendency of the animal to learn the general structure of the task, or to "learn how to learn it." After sufficient repetitions, apes are able to solve these problems after a single informing trial, i.e., they act as if they knew: "if it's not under one object, it's under the other." However, squirrel monkeys and other more primitive primates may not be able to reach this level of performance, since they require at least two trials on any block for solution, and reach that level only after considerably more trials than do the higher primates.

Our tree shrews may turn out to be equal or even superior to some of the small New-World monkeys, but more testing with naïve tree shrews is required. An earlier series of tests of "set-learning" by our Tupaia was marred by an unexpected capacity of these animals to employ minimal olfactory cues (apparently well beyond the capacity of ordinary primates). As a result, they began the series of tests at better than chance level, thereby invalidating the technique. This problem has been solved (by smearing food particles over both foodwells, in the discrimination apparatus), and new trials will be run as soon as additional animals are obtained.

In the meantime, plans are being completed for detailed tests of the tree shrews color discrimination and auditory capacity, including the possible presence of echolocation in these species. Furthermore, we shall investigate effects of selective cortical ablations on such classical tasks as delayed alternation and delayed response. Projected neuroanatomical studies include scrutiny of the central visual pathways and attempts at defining homologues in the tree shrews of such regions as the prefrontal cortex of higher primates.

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Appendix

Colloquium Program

During the six months under review - from June 1, 1963 to December 31, 1963, the Psychological Laboratories continued to sponsor colloquia by a number of guest speakers, whose names and topics are listed below. Some of these visitors spent longer periods at the laboratories, permitting daily contact with faculty and graduate students. Among those who spent a week or more as visitors in this fashion were:

Professor Jan Bures (Academy of Science, Prague, Czechoslovakia)

Professor Carolus Oldfield (Oxford University, England)

Professor Paul Fraisse (Institute of Psychology, Sorbonne, Paris, France)

Professor Donald M. MacKay (University of Keele, Staffs., England)

Professor H. Leibowitz (Pennsylvania State University, Penna., two months during the summer)

Professor S. E. Asch (Swarthmore College, Penna; entire Fall term, 1963-64)

The list of colloquia and luncheon discussions follows:

Colloquia and Luncheon Discussions

June 1 to December 31, 1963

June 4, 1963	L. Mihailovic University of Belgrade (Visiting Professor at Yale University)	Effects of Anti-Cerebral Antibodies on Brain Function
June 7, 1963	Irvin Rock Yeshiva University New York, N.Y.	One-Trial Learning
June 14, 1963	Ivo Kohler University of Innsbruck Austria	A Proposed Extension of the Von Holst-Mittelstaedt Theory of Reafferent Feedback in the Nervous System
June 25, 1963	Benjamin W. White Lincoln Laboratory Lexington, Mass.	An Experimental Critique of the Perceptron
July 9, 1963	H. Leibowitz Penn. State University State College, Penna.	Some Studies of Perceptual Constancy
July 15, 1963 July 16, 1963	Paul Fraisse, Director Institut de Psychologie Université de Paris	L'Adaptation de l'Homme au Temps La Durée de la Perception
Sept. 6, 1963	Jonathan Wegener Goshen College Goshen, Indiana	Auditory Discrimination in Monkeys
Sept. 9, 1963	J. Bures Czechoslovakian Academy of Science, Prague	Functional Dissection of the Mechanisms of Learning
Sept. 20, 1963	Richard L. Gregory Cambridge University England	Illusions and Reality
Sept. 27, 1963	S. S. Stevens Harvard University	An Extension of the Psychophysical Law
Oct. 4, 1963	L. Weiskrantz Cambridge University England	A Glimpse at the Frontal Lobes of Monkey
Oct. 11, 1963	R. C. Oldfield Oxford University England	Some Psycholinguistic Topics

Oct. 18, 1963	P.O. Bishop University of Sydney Australia	The Neurology of Visual Direction
Special Series:	Donald M. MacKay University of Keele, Staffs., England	
Oct. 21, 1963	Action, Information and Perception (general introduction)	
Oct. 23, 1963	Implicit and Explicit Representations	
Oct. 25, 1963	Hierarchic Organization and 'Property Filtering'	
Oct. 28, 1963	Perception of Space I: The Role of 'Reafference' and Sensory Integration	
Oct. 29, 1963	Perception of Space II: 'Stability' and 'Constancy'	
Nov. 1, 1963	P.D. Wall M.I.T.	The Presynaptic Control of Impulses at the First Central Synapse in the Cutaneous Pathway
Nov. 15, 1963	H. Helson Kansas State University Manhattan, Kansas	Central Facilitation and Inhibition in Simple Spot Reactions
Dec. 5, 1963	Brenda Milner Montreal Neurological Institute	Effects of Temporal-Lobe Lesions on Learning and Perception
Dec. 17, 1963	Karl Pribram Stanford University Palo Alto, Calif.	Further Analyses of the Temporal-Lobe Syndrome in the Monkey: Generalization and Transposition - Are They Dissociable?